Determination of Effects of Various Parameters on Forming Limit Diagram using FEA

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Abstract: ***Sheet metal forming is the process of converting flat sheet of metal into a part of desired shape without fracture or excessive localized thinning and widely used in aerospace, automotive, appliances industry. In sheet metal forming failure can be predicted by Forming Limit Diagram (FLD). FLD offers a convenient and useful tool in sheet products manufacturing analysis. They show the critical combinations of major strain and minor strain in the sheet surface at the onset of necking and are also used during the design stage of any new sheet metal component for tooling shape for optimizing process variables of new product development. In this research, the effect of n-value (strain hardening exponent), punch velocity & sheet thickness on FLD were studied using FE based HYPERFORM software. As new market requirements are becoming more persistence through introduction of new technologies for improvements in performance trends, these FEM based software simulation is becoming more affordable & reliable as they reduce lead time & cost. It also improves productivity & quality. A typical industrial component was chosen for analysis. The results demonstrate that FLD0 increases with increasing n-value & sheet thickness but for punch velocity more iteration are required.***

Keywords: Computer Simulation; Forming Limit Diagram; Parameters; Sheet Metal Forming.

1. Introduction

The forming limit of sheet metal is defined to be the state at which a localized thinning of the sheet initiates during forming, ultimately leading to a split in the sheet. The forming limit conventionally describes as a curve in a plot of major strain Vs. minor strain. Forming limit diagram as shown in Fig. 1 is used during the new product development for tooling shape & optimizing process variables. Successful manufacturing & quality of sheet metal component is depending on many parameters viz. lubrication, friction co-efficient, plastic strain ratio, strain rate, strain path etc. Amongst those many, effect of n-value (strain hardening exponent), punch velocity & sheet thickness have been studied using FE based HYPERFORM software.

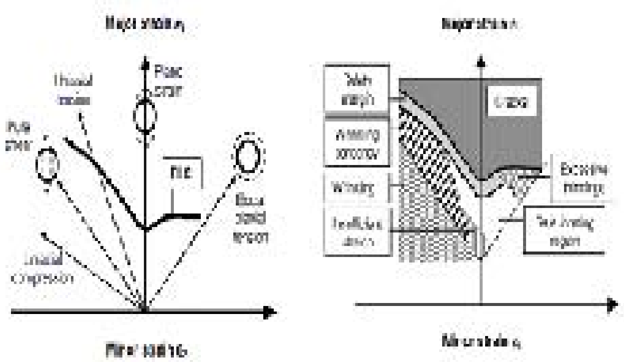

Figure 1: Forming Limit Diagram

2. Literature Review

FLD concept was first given by GENSAMER (1946) but concept was extended by KEELER (1964) and GOODWIN (1968) and represents the criteria of deep drawing operation [1]. Many efforts have been made in area of finite element simulation; Damoulis et al. [2] had used explicit finite element software PAM-STAMP 2K to calculate equivalent plastic strain & indication of failure. Kim [3] had studied the effects of process parameters like tool type, tool size, feed rate, friction co-efficient using FEM & found that formability is improved when a ball type tool with a particular size is used with small feed rate & little friction. Chandramohanreddy [4] has done work on tooling configuration, blank configuration, material properties and forming conditions and found that drawability is influenced by these factors. Bramhakshatriya [5] showed that the thickness and strain distribution pattern in hemispherical cup forming is affected by circular draw bead profile and different draw bead conditions using solid modeling software PRO-E and finite element method based software HYPERFORM.

3. Solid Modeling

Modeling was done using PRO-E software. For that a typical industrial component was chosen which included two subsequent draws. Punch, die, blank & binder were made in PRO-E software using SHELL element. The first draw & second draw manufacturing is modeled as shown in Fig. 2 & Fig. 3 respectively.

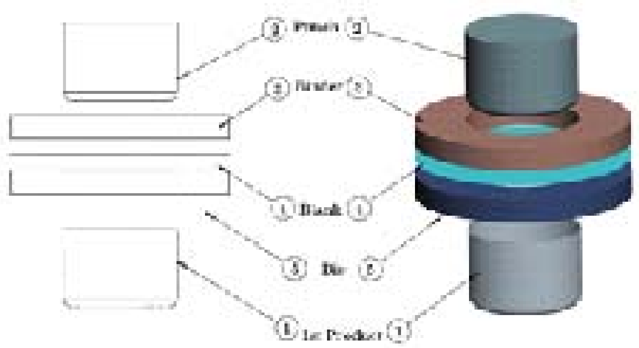

Figure 2: Solid Modeling of First Draw

In this model the material is assigned to blank & mechanical properties are shown in Table 1. This tool setup is meshed with RIGID MESH MODEL for punch, die and binder & BLANK MESH MODEL for blank.

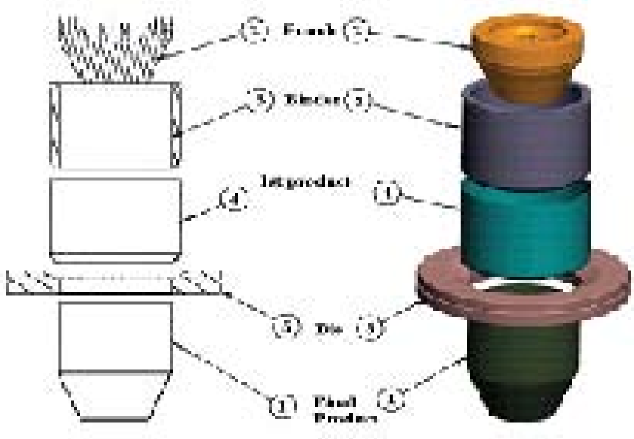

Figure 3: Solid Modeling of Second Draw

Table 1: Mechanical Properties of Material

Material		AISI 304
Density (ρ), Kg/m3		7800
Yield Strength, Mpa		307.33
Ultimate Tensile Strength, MPa		575
Strength Co-efficient (K), Mpa		1069.852
Strain Hardening Exponent (n)		0.2294
Anisotropy Index (r)	r0	1.1543
	r45	0.9474
	r90	1.0228

The blank of 1400 mm diameter & uniform thickness of 1.6 mm is assigned by the HILLORTHOTROPIC card image. The diameters of components after first and second draw are 730 mm and 630 mm respectively, with taper diameter of 292 mm in second draw.

4. Computer Simulation

In computer simulation, contact is necessary between the sliding bodies for the metal forming process. In this Study DOUBLE ACTION DRAW algorithm was used for the contact between the punch, die, blank holder and blank. The blank was treated as master surface and others were treated as slave surfaces. Different n-values were used for computer simulation between 0.20 to 0.24, different punch velocities being considered between 3500 to 5500 mm/s and different sheet thickness being taken between 1.2 to 2.2 mm.
For other n-value (0.22-0.24) simulations have been done with keeping punch velocity & sheet thickness constant similarly to Fig 4 results have been obtained.

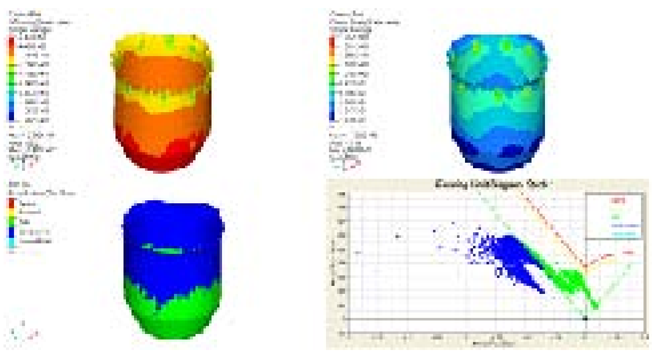

Figure 4: Effect of n-value on FLD (n=0.20, Punch Velocity= 5000 mm/s, Sheet Thickness=1.6 mm)

Similarly, for other punch velocity (4000-5500 mm/s) simulations have been carried out, keeping n-value & sheet thickness constant as shown in Fig 5.

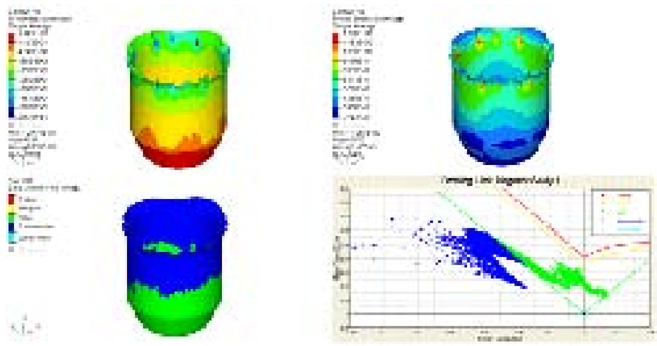

Figure 5: Effect of Punch Velocity on FLD (n=0.20, Punch Velocity=3500 mm/s, Sheet thickness1.6 mm)

As according to Fig 6 further simulations have been carried out with changing sheet thickness (1.6-2.2 mm) and keeping punch velocity & n-value constant.

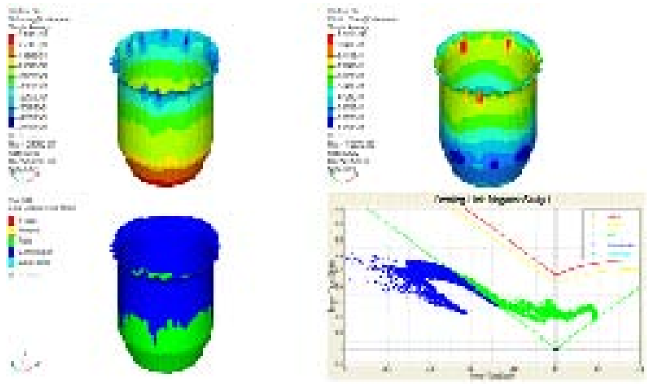

Figure 6: Effect of Sheet Thickness on FLD (n=0.20, Punch Velocity=5000 mm/s, Sheet Thickness=1.2 mm)

5. Result & Discussion

To obtain the effect of n-value, punch velocity & sheet thickness few iteration had been done on a typical industrial component with the use of HYPERFORM.

5.1 Effect of n-value on FLD

To study the effect of n-value it has been varied from 0.20 to 0.24 & it is found that FLD0 increasing from 0.34 to 0.44 respectively as shown in Fig 7.

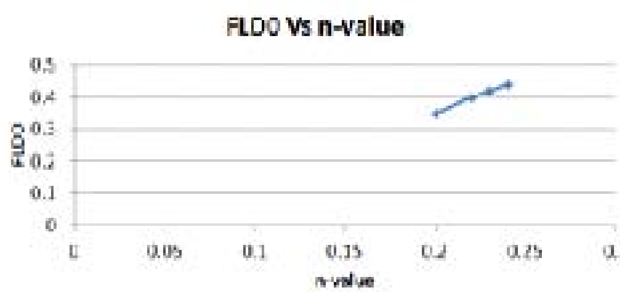

Figure 7: Effect of n-value on FLD

Table 2: Effect of n-value on FLD

n-value	*FLD0*
0.20	0.34
0.22	0.40
0.2294	0.42
0.24	0.44

5.2 Effect of punch velocity on FLD

The punch velocity is varied from 3500 to 5500 mm/s and it is found to be FLD0 is increasing from 0.41 to 0.43 respectively as in Fig 8.

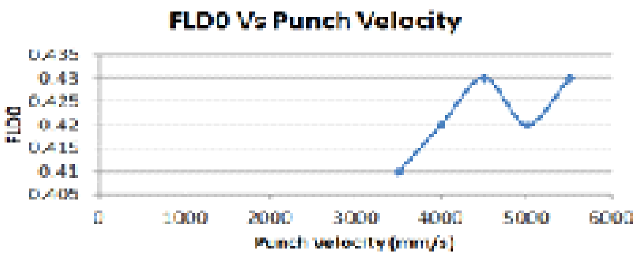

Figure 8: Effect of punch velocity on FLD

Table 3: Effect of punch velocity on FLD

Punch Velocity (mm/s)	*FLD0*
3500	0.41
4000	0.42
4500	0.43
5000	0.42
5500	0.43

5.3 Effect of punch velocity on FLD

The FLD_0 is found to be increased from 0.36 to 0.48 while increasing the sheet thickness from 1.2 to 2.2 mm respectively.

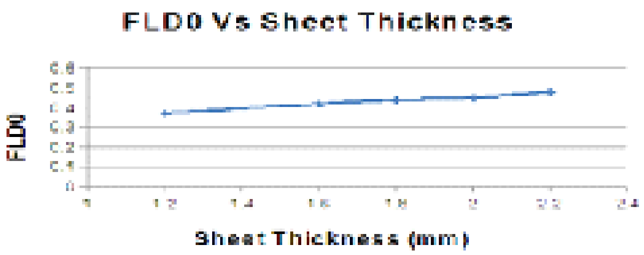

Figure 9: Effect of sheet thickness on FLD

Table 4: Effect of sheet thickness on FLD

Sheet Thickness (mm)	*FLD0*
1.2	0.36
1.6	0.37
1.8	0.44
2	0.45
2.2	0.48

6. Conclusion

Here an attempt is made to study different parameters affecting FLD like n-value, punch velocity & sheet thickness were done. For this purpose PRO-E and HYPERFORM were used. Based on the study following remarks were drawn.

• Increasing n-value from 0.20 to 0.24, FLD0 increases so that it increases formability. Also we can employ different materials according to different n-values as an alternative which will serve the purpose of cost effectiveness.

• When increasing punch velocity small variation was found in FLD0, so that existing process can be explored for formability with faster rate, which ultimately reduces time & improves productivity.

• Effect of sheet thickness shows that when sheet thickness is increased from 1.2 mm to 2.2 mm FLD0 also increases so that formability is increased.

• This work will help industry to go with computer simulation for AISI 304 material for future product development.

References

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Author Profile

Ravi Bhatt received the M.Tech. Degree in Mechanical Engineering from Nirma University in 2012. He is also certified NDT Level II candidate. He has been worked for more than two different industries involving fabrication & sheet metal forming.